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ResQ - Smart Safety Band

Automated heart rate and fall monitoring system

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***Abstract* - With an increasing trend of women and elderly people living and travelling alone, their safety has become a matter of utmost importance. In this paper, we propose a novel and innovative Internet of Things (IoT) based solution in the form of a "smart safety band". The extremely lightweight and mobile smart band is disguised as an innocuous fitness band. Various sensors interface with a microcontroller that transmits data to the web server directly. It can detect falls and sudden attacks manifesting as a spike in heart rate. If the user does not cancel in 30 seconds, a notification with user details, location and type of emergency is sent to emergency services and trusted contacts. The system can function even if the band has been destroyed after sending the first alert. Automation ensures that even if the user is incapacitated, the band automatically signals the server without requiring any user input.**

Keywords - Wi-Fi Enabled Microcontroller, Django Web Server, Machine Learning, Women Safety, Elderly Care, Micro-Electromechanical Systems (MEMS), Pulse Rate Sensor, Spike Detection, Fall Detection, Global Positioning System (GPS)

I. INTRODUCTION

Women are the victims of a disproportionately large number of crimes including rape and assault [12]. People living alone, especially senior citizens, are extremely prone to injuries or even death due to falls [13]. Approximately 28-35% of people aged 65 and over fall each year increasing to 32-42% for those over 70 years of age [13]. Over 100000 senior citizens live alone in India [14]. In these cases, the user is incapacitated and would have better chances of survival if help arrived in time.

The paper presents a smart safety band that can put the loved ones of such individuals at ease, by providing real time monitoring, and an automated alert system that can use heart rate spike detection and MEMS data to detect sudden attacks, threats and falls. The server will notify the user's trusted contacts and emergency services of any emergency reported by the band.

From the context of the women safety aspect of the paper, a state of sudden panic from an attack or accident is automatically detected and notifies the server with no intervention from the user. A mechanism to cancel this is provided using a cancel button, in case of false positives.

Existing fall detection systems perform the fall detection using a camera or kinect sensor using computer vision [16]. The problem here is that the fall can only be detected in specific locations and visibility conditions. In contrast, the proposed system requires a simple band that they can wear like a bracelet on their arm, that monitors the accelerometer and gyroscope readings to detect a fall.

The novelty of this paper comes from the automated and hardy nature of the band. It works with 0 input from the user for detection, and the user can easily cancel in case of a false positive. This ensures that even if the user is incapacitated, such as due to becoming unconscious or restrained, the alert still goes out.

The two functionalities, heart rate monitoring and fall detection, are integrated onto the same band, and provided to all users of the band.

Section II of this paper describes the literature survey of multiple papers, Section III explains the proposed model of the system, Section IV talks about the experimentation and result of the system which has been proposed, Section V contains the conclusion and Section VI includes the future scope of the paper.

II. LITERATURE SURVEY

Rapid advances in research and technologies, particularly in Micro-electromechanical Systems (MEMS), has broadened the horizons of elderly care systems. Sensor-based wearable technologies have played an important role in the development of Human Activity Recognition (HAR) applications that monitor a person's activities in a non-invasive manner. In this section, we conclusively review the advantages and disadvantages of existing similar systems/applications in the field of remote monitoring based elderly care and woman safety systems.

Wang et al. [2] reveals interesting insights on how various monitoring systems can be used in effective elderly care. Particularly, modern monitoring and alarm systems, coupled with state-of-the-art algorithms, can ameliorate adverse effects of sudden unpredictable events like illnesses, falls, etc. One of the primary functions of most elderly care systems is Human Activity Recognition (HAR). There are three major ways of implementing HAR in wearable technologies for elderly care as per Wang et al. [2]. Given the obvious disadvantages of visual and radio based recognition in cost, range and accuracy, Sensor-based HAR technologies, especially those using MEMS sensor technologies, are perfectly suited to elderly care applications.

The use of micro-controller technologies such as Arduino and Raspberry Pi in elderly care and remote monitoring systems has seen a massive surge in the last decade. Gupta et al. [1] proposed a remote monitoring healthcare system using Raspberry Pi. The proposed system primarily used a Raspberry Pi as a gateway to aggregate ECG data from different wearable technologies. This data was continuously fed and stored on a cloud-hosted data lake implemented using a MySQL database. In addition to this, an alerting system using a wireless network (GSM) was used to send an alert to the doctor in case of an emergency. The data was made available to access by authorised people using a web application.

WonedRing [3] is an excellent example of a Sensor-based HAR technology. It is essentially a wearable technology for elderly care that can be used to monitor the everyday life activities of elderly people. User data is stored in databases with a system filter to filter out useful data. The aggregated relevant data can be sent to their supporters such as family members, doctors or neighbours who can then use this information to know about their health status and thus ensure their safety. This system challenges to solve the issues faced with HAR, filtering out the useful information and consequently delivering the filtered data to an authorized party in a non-invasive manner.

A person's smartphone can serve as an excellent gateway for communicating with wearable sensor technologies. Chanhee et al. [5] showed how patients can be monitored through sensors impeded on users mobile or wearables such as heart rate sensors in modern smart watches. In order to filter the overload/sensor data, the system proposed a solution constructed through a database querying facility which utilized Sensor Network Query Processor (SNQP) and Sensor Network Query Language (SNQL) to improve data acquisition for sensor network databases.

SW-SHMS [6] leverages native characteristics of smart-phones and wearable sensor technologies to monitor elderly people in real time. Physiological data is collected from a patient using a wearable device. This data is stored in a cloud-hosted data-lake which can be accessed by authorised personnel at any given time and from anywhere. The system essentially functions as a tri-layered architecture to achieve the system goal with the three layers being Patient Layer, Data Layer and the Monitoring Platform respectively.

The use of MEMS-based wearable technologies is not limited to elderly care systems. The paper "IoT Based Smart Security Gadget for Women's Safety" provides a swift responding and reporting safety device for women. The approach is that during an emergency situation, the victim can request for help by pressing a button located on the band, which is integrated with various sensors. Once the button is triggered, information such as location, body posture, pulse rate and SMS alert are sent to the predefined number by using the GSM through Raspberry Pi.

This approach offers various advantages such as enhanced security, complete automation, affordability, simple asset recovery and tracking. In addition, the device consumes less power and is comfortable and easy to wear. This could be a plausible solution to reduce crime against women. A future enhancement can be to integrate the band with a camera, to capture images that could be sent to the emergency contact as well. [4]

III. PROPOSED MODEL

In this paper the novel system which is proposed has the block diagram as shown in Fig 3.1 and the circuit diagram as shown in Fig 3.2.

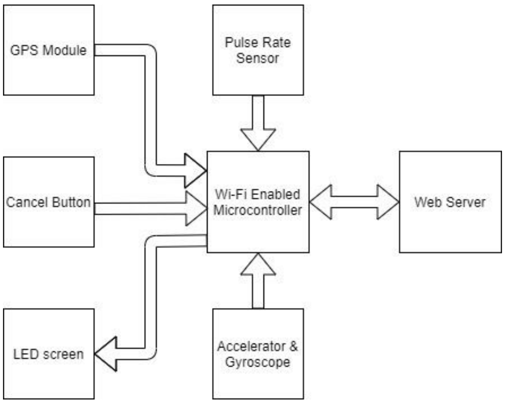

Fig. 3.1. Illustration of ResQ - Smart Safety Band

The Wi-Fi enabled microcontroller is one of the most important components of this system. It reads the parameters of various sensors like the GPS Module, the cancel button, the pulse rate sensor, the accelerometer, and gyroscope module. It processes the information from the accelerometer and gyroscope (MEMS) module to detect if a fall has taken place and at the same time constantly sends data to the web server.

The Web Server has multiple uses. Firstly, the band only needs to make one request, the server handles the rest, so bad network issues are mitigated. Heart rate spike detection is also done on the server. Even if the band is destroyed, the server shall continue the timer and notify emergency services and trusted contacts.

Pulse Rate Sensor is used to detect the heart rate of the wearer. It gives live data of the heart rate, which is sent by the microcontroller to the server. This data is used to detect spikes in the heart rate, which can indicate an attack on a woman or a heart attack.

The GPS Module gives the exact location of the wearer. The live location is constantly sent to the server, so that even if the band is broken, the last location can be retrieved. It is most useful as it gives the last known location of the wearer for authorities and trusted contacts.

The accelerometer and gyroscope module is used in the band to detect when the wearer has fallen. This raw live data is used by the microcontroller's algorithm to give a fall prediction, which is sent by the microcontroller to the server.

Cancel button is a simple push or touch sensitive button which the wearer must press within 30 seconds of a fall or heart rate spike being detected. If not pressed within 30 seconds, the emergency services and trusted contacts are notified.

LED Screen is used to display live data and status from the microcontroller. The alert for the emergency is also shown here, along with the timer.

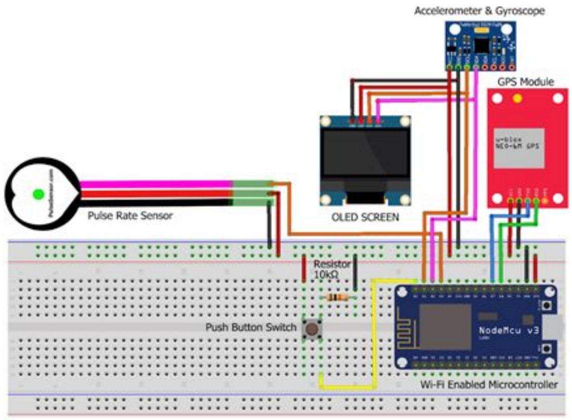

Fig. 3.2. Circuit Diagram of ResQ - Smart Safety Band

To detect the spike in heart rate, the exponential updated means algorithm is employed. This uses the concept of weighted means to cache the mean of the heart rate and the mean of the spikes in the heart rate. Spike is calculated as the difference between current and most recent heart rate value. This gives a reliable and extremely fast summary of data from before that can be used to predict whether the current spike is above normal (such as gradual increase during exercise or waking up in the morning). This method also tailors the evaluations on the basis of each individual user's health and history.

$$M(n) = \frac{2(x(n) - M(n-1))}{n} + M(n-1) \tag{1}$$

where M(n) is the exponential mean for the nth period, x(n) is the nth data point, M(n-1) is the exponential mean for the previous period.

To detect a fall, the microcontroller thresholds the MEMS data accurately distinguishing between hand movements and falls. the evaluation is kept relatively simple as it is performed by the microcontroller and can improve in the future scope.

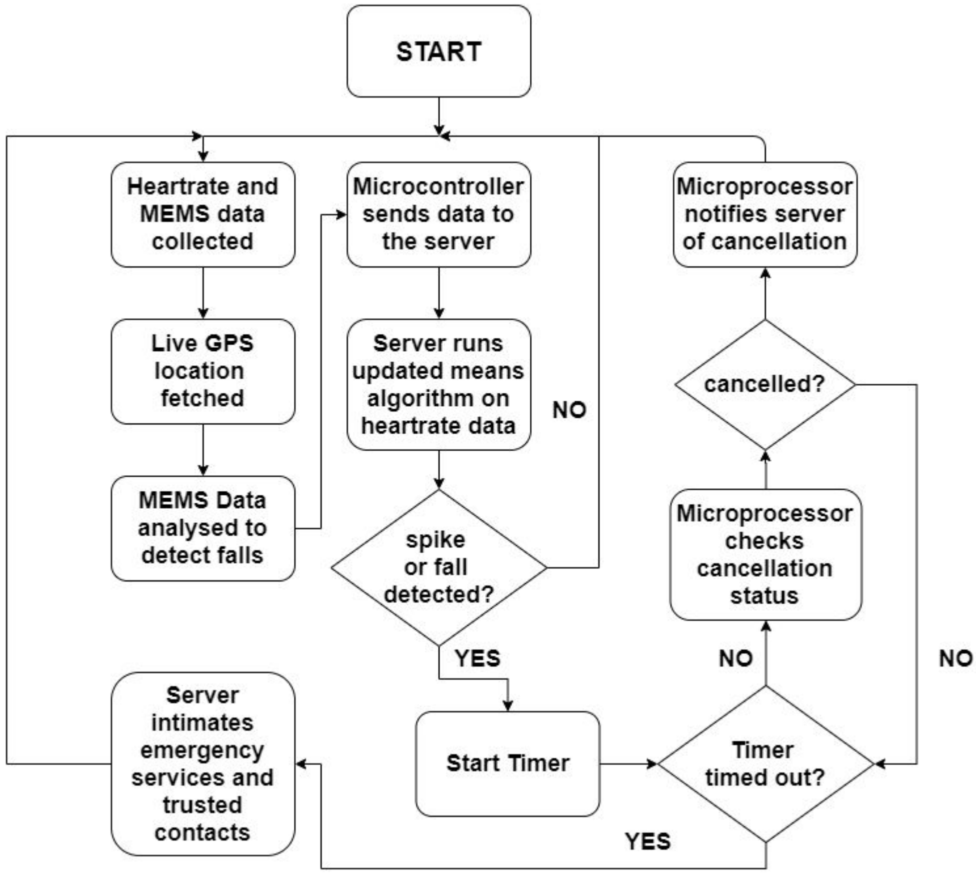

Fig. 3.3. Flowchart of proposed System

Figure 3.3 shows the flow of the Proposed Model consisting of the following steps:

Step-1: Live sensor data is sent to the Wi-Fi enabled microcontroller.

Step-2: The Wi-Fi-enabled microcontroller runs thresholding algorithms on the data to detect a fall. The live status of whether a fall is detected, along with the location is sent to the webserver through the Wi-Fi enabled microcontroller.

Step-3: The server starts a timer of 30 seconds if fall or spike is detected.

Step-4: While the timer has not timed out, the user can cancel the emergency state using the cancel button.

Step-5: If the timer has not run out and the user has pressed the cancel button, the server is notified of this cancellation.

Step-6: If the timer has run out before the button is pressed, the server notifies emergency services and trusted contacts about the emergency. It communicates the nature of the emergency (Fall or Spike), user information and exact location of the us.

IV. EXPERIMENTATION AND RESULT

For the implementation of this paper, a proof of concept was built using a Django web server (Fig 4.3 and 4.4), with the band implemented using a breadboard with a Node MCU (ESP 8266) as the wifi enabled microcontroller (Fig 4.1 and 4.2). The location of the band is also visible on the dashboard.

The web server allows simulation of an attack and shows a graphical representation of past data received from the NodeMCU. In Fig 4.1 and Fig 4.2, wiring is used to connect the components instead of a printed circuit board. Tbe power source is a power bank which can be switched to a battery.

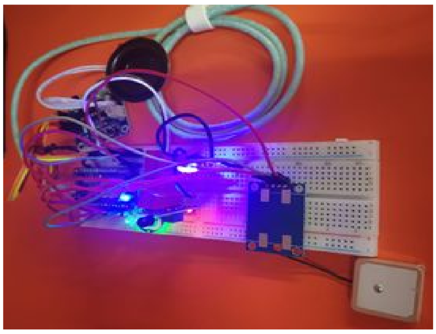

Fig. 4.1. Hardware Implementation View -1

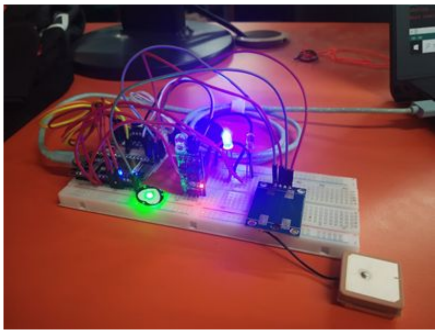

Fig. 4.2. Hardware Implementation View - 2

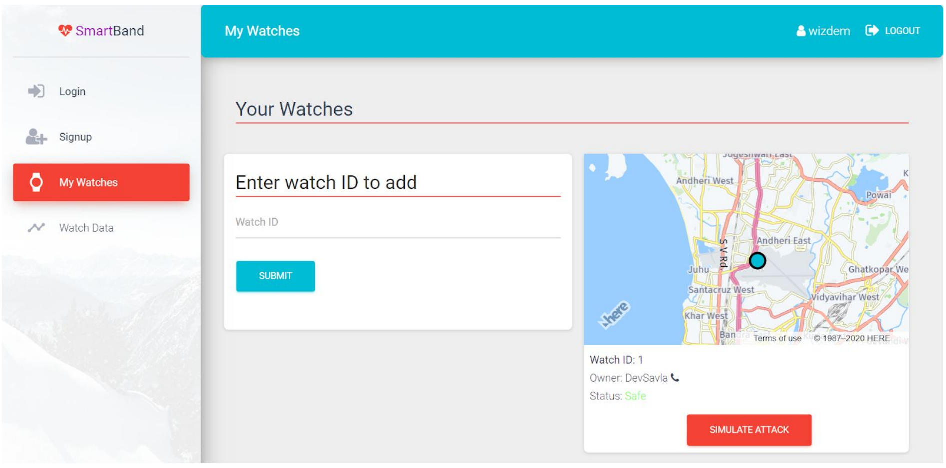

Fig. 4.3. Dashboard View - 1

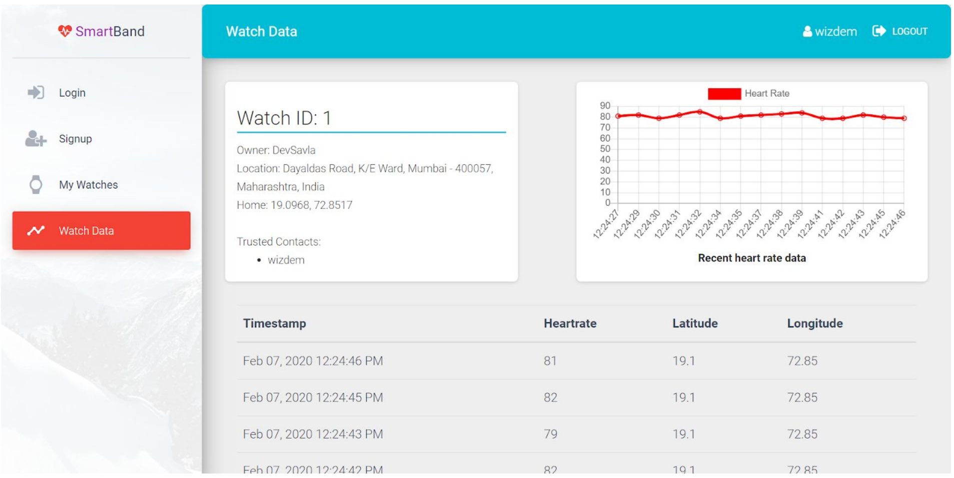

Fig. 4.4. Dashboard View - 1

V. CONCLUSION

The proposed design deals with important issues regarding women safety and elderly care and solves them with technologically sound equipment and innovative ideas. The major merit of this work is that it enhances personal safety. It provides security by real-time monitoring. Since the proposed device does not rely on any sensitive user data except for user location, it provides these advantages in a non-invasive manner.

VI. FUTURE SCOPE

Mobile App: A mobile app for live tracking of data and additional data analytics can be introduced. It will also be helpful for various settings related to the system, such as adding trusted contacts and turning on and off certain features. It also lets the band get direct network connectivity via the user's mobile phone instead of its own Wi-Fi module.

Buddy System: Complementary to the mobile app, a mechanism to inform nearby users that an emergency has occurred can also be devised. This helps call for quicker help in case the user is in trouble far away from their trusted contacts and emergency services are taking time to reach.

Authenticated Cancellation: The cancel button can be replaced by a fingerprint reader and microphone that require the user to either use fingerprint or voice command to cancel. This prevents cases like the attacker pressing the cancel button or it getting pressed accidentally on falling.

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